Lithostratigraphic differentiation of the Gavrovo and the Ionian flysch in the Southern Akarnania and the role of the Agrilia and Evinos transverse fault zones*

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ABSTRACT: A substantial flysch succession is exposed between the city of Mesolongi and the highs of Klokova and Varasova. In this paper, a schematic section is provided, showing the lithostratigraphy and highlighting the differentiations between the Ionian and the Gavrovo flysch formations. Data on the distribution and thickness of coarse lithologies suggest the presence of two main sources of sediment supply. A northern source towards the western part of the study area, linked to the Ionian unit and a southern source that dominates the eastern part associated to the Gavrovo unit. The western section of the flysch, incorporated within the Ionian unit, cannot be correlated to the eastern part that is classified within the Gavrovo unit, implying that the flysch is not common for both units, as it has been proposed by other workers in the past. Alternatively, it is supported that there is a boundary within the flysch, although weak in lithostratigraphic terms that is also linked to the paleogeography of the area, separating the Ionian from the Gavrovo flysch.

The Ionian and the Gavrovo flysch sequences were deposited synchronously, in two separate basins, which were divided by the thrust/tectonic boundary. This boundary produced a topographic relief, which acted as a barrier, preventing and/or restricting the expansion of conglomerates towards the west, as well as the expansion of the Arakinthos sandstones to the east. In addition, the absence of conglomerates towards the west indicates that the Gavrovo basin was under filled.

Additionally, two major NE-SW trending transverse fault zones (Agrilia and Evinos) have a pronounce effect on the lithostratigraphy. A significant vertical offset is evident for both the Agrilia and the Evinos fault zones, questioning the available published data that consider them as pure strike slip faults. Both zones controlled the lithostratigraphy in the past, but at present day show no sign of activity and can be characterized as predominantly syn-sedimentary structures. The latter is more clearly demonstrated for the Evinos fault zone, where an horizontal displacement of only 150m is observed, offsetting lower-middle members of Oligocene age of the Gavrovo flysch succession, implying that the main phase of the Evinos fault zone activity, predates the deposition of those horizons.

Key-words: *Ionian Unit, Gavrovo Unit, External Platform, Mesolongi, Aitoloakarnania, faults.*

ΠΕΡΙΛΗΨΗ: Κύριο χαρακτηριστικό της περιοχής μελέτης που εκτείνεται από την πόλη του Μεσολογγίου μέχρι και τα υψώματα της Βαράσοβας και της Κλόκοβας, αποτελεί η ευρεία παρουσία φλυσχικών αποθέσεων μεταξύ των γεωτεκτονικών ενοτήτων της Ιονίου, που εμφανίζεται προς το δυτικό τμήμα, και του Γαβρόβου που εμφανίζεται στο ανατολικό τμήμα της. Η παρούσα εργασία παρουσιάζει μια ολοκληρωμένη εικόνα της λιθοστρωματογραφικής διάρθρωσης της περιοχής, εντοπίζει τις όποιες λιθοστρωματογραφικές διαφορές διακρίνονται στον φλύσχη των δύο ενοτήτων, και τέλος αποκρυπτογραφεί την επίδραση των ρηξιγενών ζωνών του Εύηνου και της Αγριλιάς στην λιθοστρωματογραφία. Με βάση την λιθοστρωματογραφία, συμπεραίνουμε ότι ο φλύσχης δεν είναι κοινός και ότι το δυτικό τμήμα του, το οποίο και εντάσσεται στην Ιόνια ενότητα, δεν μπορεί να συσχετιστεί με το ανατολικό που εντάσσεται στην ενότητα Γαβρόβου. Οι διαφοροποιήσεις μεταξύ του φλύσχη της Ιονίου και του Γαβρόβου συνίστανται: στις συνθήκες μετάβασης από την ανθρακική ιζηματογένεση στην κλαστική, στη λιθολογική σύνθεση των σχηματισμών του φλύσχη αλλά και στη λιθολογική σύνθεση και το εύρος των ψαμμιτικών οριζόντων ειδικότερα, καθώς και στις διαφορετικές πηγές τροφοδοσίας των δύο ενοτήτων. Με βάση την κατανομή και το πάχος των αδρομερών λιθολογιών, ως προς την προέλευση του φλυσχικού υλικού της Ιόνιας ανιχνεύεται μια πηγή τροφοδοσίας από τα βόρεια, ενώ ως προς την προέλευση του αντίστοιχου φλυσχικού υλικού της ενότητας Γαβρόβου μια πηγή τροφοδοσίας από τα νότια. Οι διαφορετικές πηγές τροφοδοσίας υποδεικνύουν τις διαφορετικές παλαιο-γεω-γραφικές συνθήκες μεταξύ των δύο ενοτήτων και σχετίζονται άμεσα με την δομή και θέση των γεωτεκτονικών ενοτήτων στην περιοχή.

Οι δύο φλυσχικές ακολουθίες του Γαβρόβου και της Ιονίου αποτέθηκαν ταυτόχρονα, αλλά σε δύο ξεχωριστές λεκάνες, οι οποίες διαχωρίζονταν από το όριο της επώθησης. Το όριο αυτό πιθανότατα επέδρασε και στην τοπογραφία, δημιουργώντας ένα ανάχωμα το οποίο λειτούργησε ως φράγμα, αποτρέποντας την επέκταση τόσο των κροκαλοπαγών της Βασιλικής προς τα δυτικά, όσο και των ψαμμιτών του Αράκυνθου προς τα ανατολικά. Το γεγονός αυτό υποδεικνύει ότι η ανατολική λεκάνη (του Γαβρόβου) δεν υπερπληρώθηκε.

* Διάκριση λιθοστρωματογραφίας του φλύσχη Ιόνιας και Γαβρόβου στη Νότια Ακαρνανία και ο ρόλος των εγκάρσιων ρηξιγενών ζωνών του Εύηνου και της Αγριλιάς.

Οι ρηξιγενείς ζώνες του Εύηνου και της Αγριλιάς προκαλούν σημαντικές διαφοροποιήσεις στη λιθοστρωματογραφία από όπου προκύπτει μια μεγάλη κατακόρυφη συνιστώσα άλματος και για τις δύο ζώνες. Το γεγονός αυτό υποδηλώνει ότι οι ζώνες αυτές λειτούργησαν καθοριστικά κυρίως κατά το στάδιο απόθεσης των σχηματισμών και παράλληλα έρχεται σε αντίθεση με τις υφιστάμενες βιβλιογραφικές αναφορές με βάση τις οποίες χαρακτηρίζονται ως ζώνες οριζόντιας ολίσθησης. Ειδικότερα για την ρηξιγενή ζώνη του Εύηνου προκύπτει μια κατακόρυφη συνιστώσα άλματος μεγαλύτερη του ενός χιλιομέτρου, λαμβάνοντας όμως υπ' όψιν και τους προορογενετικούς σχηματισμούς, σε αντίθεση με την οριζόντια συνιστώσα η οποία είναι περιορισμένη και δεν ξεπερνά τα 150 μέτρα, όπως αυτή εκφράζεται από τη μετατόπιση των κατώτερων προς μεσαίων μελών του φλύσχη.
Λέξεις-κλειδιά: *: Γάβροβο, Ιόνια, Εξωτερική πλατφόρμα, Μεσολόγγι, Αιτωλοακαρνανία, Ρήγματα.*

INTRODUCTION

The area widely known as the Akarnania syncline is situated between the city of Mesolongi and the highs of Varasova and Klokova. It is also known as the area of the common flysch succession due to the broad presence of clastic deposits, which form a "common flysch" between the Ionian and the Gavrovo geotectonic units (e.g. DERCOURT *et al.*, 1977). The Ionian unit extends towards the western part of the area, whereas the Gavrovo unit outcrops to the eastern part (Fig. 1). Both units are part of the External Carbonate Platform of the Hellenides, which constitute the more external tectonostratigraphic Terrain H1 (PAPANIKOLAOU, 1997; PAPANIKOLAOU *et al.*, 2004). The H_1 Terrain was a continuous shallow water carbonate platform throughout the Upper Triassic-Lias (PAPANIKOLAOU *et al.*, 2004). The main difference between the Ionian and the Gavrovo unit is the paleogeographic change that occurred in the Ionian during Late Lias (PAPANIKOLAOU, 1986a) when taphrogenetic processes (KARAKITSIOS, 1992) divided the water platform in two parts. One part that remained shallow throughout Late Triassic-Eocene (Gavrovo and Tripolitsa units) and another part (Ionian unit), which formed a deeper basin (PAPANIKOLAOU, 1997). Orogenetic processes initiated at early Tertiary (Late Eocene-Oligocene) on both units.

The perspective of this paper is: i) to present a complete picture of the lithostratigraphic structure, ii) to trace any lithostratigraphic differences within the so-

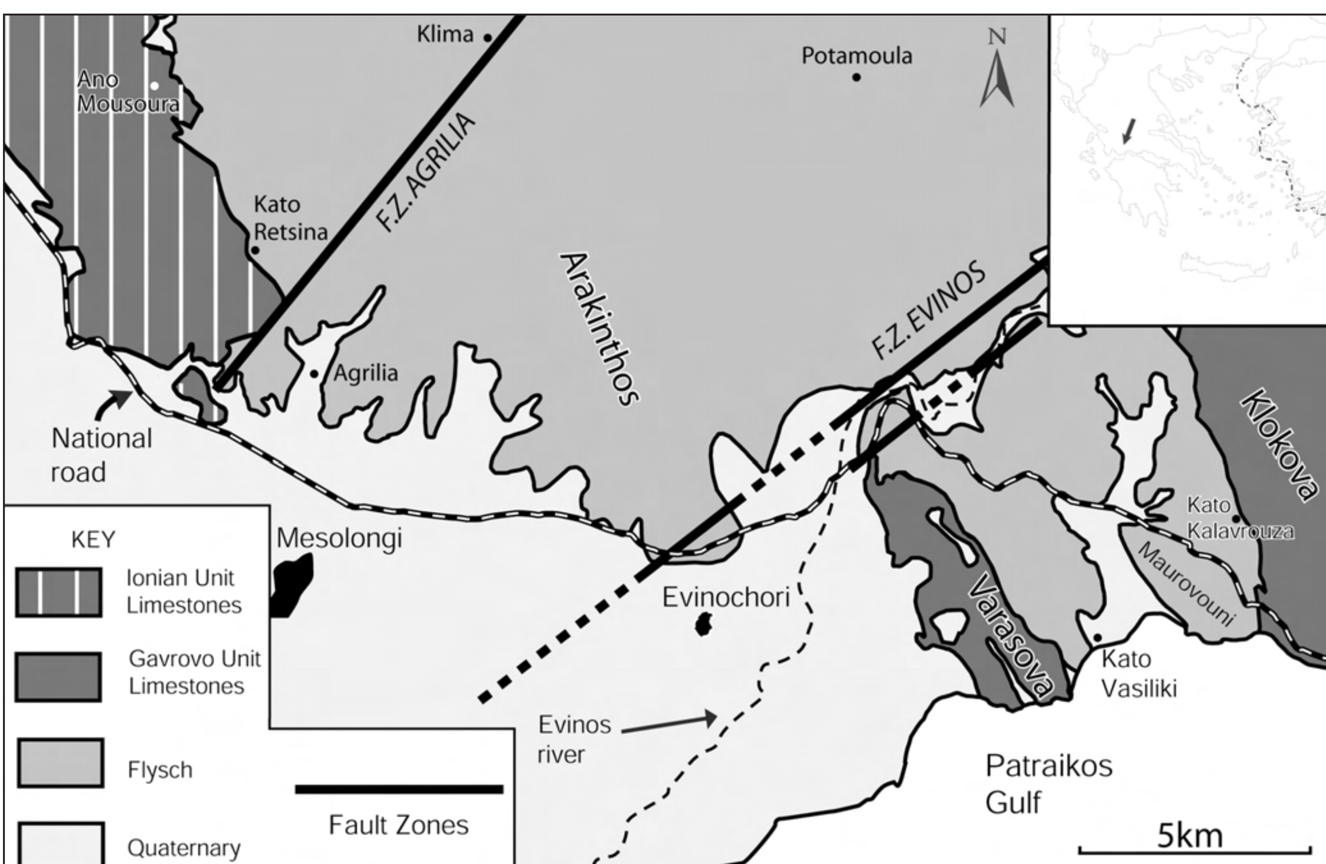


Fig. 1. Simplified geological map of the southern Aitoloakarnania.

called "common" flysch that would allow us to differentiate or divide and incorporate it, into one of the two geotectonic units outcropping in the area and iii) to unravel the influence of the Evinos and Agrilia fault zones in the lithostratigraphy.

REGIONAL SETTING - LITERATURE OVERVIEW

The Klokova and Varasova highs are the prominent features in the area. Primary studies involving both highs took place in the late 19th century (NEUMAYR, 1880; PHILIPPSON, 1890), and early on they have been correlated with facies from Gavrovo and Tripolitsa in Epirus and Peloponnesus, respectively (PHILIPPSON, 1890; AUBOUIN *et al*., 1958; AUBOUIN, 1959; AUBOUIN & NEWMANN, 1959; AUBOUIN & DERCOURT, 1962). AUBOUIN (1959) described the transition from the Eocene limestone to the flysch deposits, towards the upper part of the Klokova section, in the Upper Lutetian - Lower Priabonian, as normal, though abrupt. BIZON *et al*. (1963), also at the same locality concluded that there is a normal transition between the underlying Upper Lutetian – Lower Priabonian neritic limestones and the overlying Upper Eocene (*Globorotalia turritilina*) or Lower Oligocene (*Globorotalia oligocenica*) flysch. According to BIZON *et al*. (1963) the transitional beds (5-10 cm thick carbonate beds alternating with very fine marly material) are of Priabonian age (*Pellatispira madaraszi* HANTKEN) and have a total thickness of 2.5 m. AUBOUIN (1959) also purported that both the Ionian and Gavrovo flysch are very similar, but he observed that the Gavrovo flysch comprises large bodies of coarse-grained cohesive conglomerates, which are absent from the Ionian zone and that the Ionian zone can be characterised as more marly compared to the Gavrovo zone. Finally, based on the presence of *Globorotalia* sp. and *Globigerina* sp. in reddish marly limestones at the base of the flysch, he concluded that the transitional beds of the Ionian zone are of Priabonian age. The latter is in agreement with studies conducted later by FLEURY (1980) who suggested that the transition from carbonate to clastic sedimentation occurred during the Priabonian and more specifically close to the Eocene – Oligocene boundary.

Researchers of the B.P. (1971), introduced the first 1:100.000 scale geological map based predominantly on Aerial photographs. Among others, they suggest that the Ionian zone outcrops also in Akarnania and is exposed west of the imaginable straight line crossing through the Agrinio city northwards and the Varasova high southwards. Although most of the paleocurrents in the Ionian trench were parallel to the axis of the trench trending towards the north or the south, a significant transverse paleocurrent was evident to the east, from where the greatest volume of the material originated. In contrary, to the previous researchers, they suggested that there is a disconformity between the flysch and the underlying Eocene limestone and that the flysch sedimentation began in the Lower Miocene. Additionally, they divided the area into five different lithological groups and identified two NE-SW trending right-lateral strike-slip faults; the Agrilia fault and the Evinos fault. Finally, they supported that the Klokova and Varasova anticlines extend up to the coastline and are possibly offset by a right-lateral fault along strike of the Partraikos gulf.

PIPER *et al*. (1977, 1978) studied the sedimentology and mapped the south Akarnania flysch in the area located between the lake Trikhonida and the Patraikos gulf. They disagreed with the flysch classification and the correlation of different lithological groups proposed by B.P. (1971) and offered a different pattern. According to their interpretation the flysch is divided into six different stratigraphic units, which are the following:

- The Evinos shale unit that overlies the Eocene neritic limestone of the Gavrovo zone, is approximately 700 m thick and is being cut locally by thick conglomerate and massive sandstone of the Gavrolimvi Conglomerate.
- The Gavrolimni Conglomerate, which is located within the Evinos unit and is mainly composed of large conglomerate lenses and sandstones. It is 60-80 m thick and outcrops at the southwest of Klokova and to the northern slopes of Varasova.
- The Ellinika sandstone unit that is approximately 1300 m thick, consists of sandy flysch formation and outcrops both towards the west overlying the Eocene limestone of the Ionian zone as well as to the east overlying the Evinos shale unit.
- The Potamoula shale unit, which overlies the Evinos shale unit and the Ellinika sandstone unit, is a predominantly shale succession around 1200 m thick with local massive sandstone and sandy flysch, and outcorps mainly eastern of the Varasova-Froksilia anticline.
- The Arakinthos Sandstone unit that is the most characteristic formation of the area, comprises massive sandstone, outcrops only west of the Varasova-Froxilia anticline and overlies the Potamoula formation. The Arakinthos sandstone unit was probably situated towards the eastern limb of the Varasova-Froxilia anticline as well, but now is absent probably due to erosion processes.
- The Karitsa shale formation, which is the highest strata exposed in the area and is about 150 m thick.

Following paleocurrent measurements, PIPER *et al*. (1977, 1978) identified two main sources of sediment supply in the region, one near the eastern end of Trichonis lake and the other along the gulf of Patras, that were probably deltas building out across a narrow shelf. The sediments were deposited in two overlapping deep sea fans. PIPER *et al*. (1977, 1978) supported that the northern source, located near the eastern margin of Trichonis lake supplied the coarse sands and conglomerates of the Potamoula shale unit near the village of Klima and the Arakinthos sandstone. The southern source was located along the present gulf of Patras and supplied the Gavrolimni conglomerates, many of the sandstones and conglomerates of the Ellinika sandstone unit around Agrilia village and the sandstones of the Potamoula shale formation west of Koutsoheri village. Overall, the southern source supplied the lower section of the flysch succession while the northern source supplied the upper section of the flysch succession.

FLEURY (1980), provided a detailed stratigraphic analysis both for the Klokova and Varasova highs. He supported that the limestone flysch transition towards the western flanks of the Klokova high occurred during the Oligocene, through the formation of transitional beds. The transition beds are a few meters thick and the transition can be characterized as abrupt. In Varasova, FLEURY (1980) revealed the replacement of Middle-Upper Eocene planktonic fauna by benthonic and correlated them with the formation of the bauxite horizon in Klokova, indicating a sharp decrease in sedimentation depth.

More recently, SOTIROPOULOS *et al*. (2003) subdivided the eastern part of the flysch into the Etoliko unit (thin-bedded turbidites up to 1700 m thick of shaly flysch at the bottom and a more sandy flysch at the top dated from early to middle Oligocene times) and the Aghios Georgios unit (up to 1500 m thick massive sandstones and conglomerates at the bottom and marly siltstones with intercalations of thin-grained sandstones and slumps at the top dated from middle to late Oligocene times). Based on seismic reflection data, SOTIROPOULOS *et al*. (2003), supported that there are probably two thrusts the Arakinthos and the Gavrovo thrusts, which are most likely linked at depth forming the Arakinthos-Gavrovo thrust. Therefore, they claimed that the Gavrovo-Arakinthos thrust represents an out of sequence thrust system that was splayed into two thrusts and acted simultaneously to the Pindos thrust. They calculated movements of at least 10 km and a mean shortening rate of 1mm/yr.

One of the major issues concerns the initiation of the flysch sedimentation with scientists arguing for a Late Eocene-Lower Oligocene (AUBOUIN, 1959; I.F.P., 1966; FLEURY, 1980) or Lower Miocene age (B.P., 1971; JENKINS, 1972). Micropaleontological analysis performed by PAVLOPOULOS (1983) towards the region of Makrinoros located north of the study area, suggested that the base of the flysch is of Upper Eocene (Priabonian) age. Moreover, detailed biostratigraphic analysis based on nanofossils support that the flysch in the Akarnania region belongs to the N.P.22/23/24/25 zones of Oligocene age (KISSEL *et al*., 1985; SOTIROPOULOS *et al*., 2003).

The main question arising from the study area was expressed by PAPANIKOLAOU (1986a, 1986b) who highlighted the importance of demonstrating whether a common flysch exists or not, because it can indicate if there is an horizontal transition between the Ionian and Gavrovo units in the Mesolongi - Varasova region. Therefore, either there is an horizontal transition within 5 km and the flysch is indeed common, as observed in the western part of Epirus mainland, a few hundrend of kilometers north (e.g. I.F.P., 1966; DERCOURT *et al*., 1977), or there is a buried thrust of the Gavrovo unit on the Ionian unit, indicating that thrusting was contemporaneous to the flysch sedimentation.

Based on the literature review described above, the following conclusions can be drawn:

- Mapping and division of the flysch into different stratigraphic units varies significantly from researcher to researcher and different interpretations exist (B.P., 1971; PIPER *et al*., 1977, 1978; METTOS & KARFAKIS, 1991; KOURIS, 1996; SOTIROPOULOS *et al*., 2003). This is attributed not only due to the vast area covered by the flysch, but also due to the complex and chaotic picture of its internal structure.
- There is a debate concerning the age of the flysch sedimentation. However, most scientists now agree that the flysch sedimentation initiated close to the Eocene-Oligocene boundary and continued up to Upper Oligocene times.
- Paleocurrent studies revealed the presence of two main sources of sediment supply. One source was located near the eastern end of the Trichonis lake and the other source was located towards the present gulf of Patras and closer to the eastern part of the study area whose material was predominantly of Pindos unit origin.
- Based on the lithostratigraphy the flysch succession cannot be easily differentiated, divided or incorporated to each geotectonic unit and is considered as one common formation. However, some researchers (e.g. AUBOUIN, 1959) supported that the western part of the flysch is more marly and the conglomerates are absent, whereas towards its eastern part, the flysch is dominated by coarser lithologies such as conglomerate.

GEOLOGY – LITHOSTRATIGRAPHY

Introduction

Mapping and division of the flysch into different stratigraphic units is a difficult task, not only because of the vast area covered by the flysch, but mainly due to the complex and chaotic internal structure. As a result, research groups in the past provided considerably different lithostratigraphic interpretations, considering the flysch as one common formation (e.g. B.P., 1971; PIPER *et al*., 1977, 1978; ALEXANDER *et al*., 1990; GONZALEZ-BONORINO, 1996). Alternatively, we focus our attention on trying to distinguish, based purely on lithostratigraphic terms, the Gavrovo unit flysch from the Ionian unit flysch (Fig. 2). We provide a schematic section showing the lithostratigraphy of the area (Fig. 3), based both on field-work observations and the study of Aerial photographs. Additionally, we present how the Agrilia and Evinos fault zones affect the lithostratigraphic structure.

The lithostratigraphy cannot be presented as a single lithostratigraphic column for each unit. Instead we present a number of columns attached to different localities within the study area (Fig 3). Following this approach, we offer a broad picture of the lithostratigraphic structure, from which we can easily: i) trace all variations observed concerning the phase and thickness of the sediments involved, and ii) distinguish how different lithological groups and formations correlate spatially.

The Gavrovo Unit

Gavrovo flysch Formation. The Gavrovo flysch outcrops towards the eastern part of the study area and overlies the carbonate formations of the Gavrovo unit. The transition from carbonate to clastic sedimentation occurs either through a few meters thick marly material at Klokova (BIZON *et al*., 1963), named herein as the Kalavrouza beds (described in the following paragraphs), or through an unconformity observed between the neritic limestone and the conglomerate of the Vasiliki member towards the eastern flanks of Varasova (FLEURY, 1980). Flysch sedimentation initiated during the Upper Eocene (AUBOUIN, 1959; BIZON *et al*., 1963) or Lower Oligocene times (FLEURY, 1980; SYMEONIDIS *et al*., 1987; METTOS & KARFAKIS, 1991; SOTIROPOULOS *et al*., 2003). The total thickness of the Gavrovo flysch formation exceeds 1600 m. The following members were identified within the flysch formation and are presented from recent to oldest:

- **Potamoula Shale Member.** It consists of shales with alternating layers of marly clays and fine-grained sandstones. No conglomerates are observed. This member represents the upward evolution of the Gavrolimni sandstone member as well as the lateral northward evolution of the Gavrolimni sandstone and the Vasiliki conglomerate members. The Potamoula shale member outcrops towards the north-northeastern part of the study area (north of Evinos river and near to the Potamoula village). It forms a relatively smooth relief, with few morphological discontinuities observed solely at localities where sandstones emerge.
- **Gavrolimni Sandstone Member.** It consists of 5-10 m thick cohesive sandstones, frequently alternating with shales, whereas in few locations conglomerate horizons were also recorded. Sandstone beds trend NNW-SSE and many are folded with a similar NNW-SSE trending axis. South of the Evinos river and towards the western flanks of Klokova sandstone, beds dip towards the SW, whereas at the eastern flanks of Varasova, they dip to the NE. North of the Evinos river, strata generally dip towards the NE. However, at several localities close to Psorolithi and Kokaliara highs, beds are heavily deformed and in places inverted, due to intense folding. Gradually, most sandstone beds taper northwards, whereas others evolve laterally towards the Potamoula Shale member. The total maximum thickness of this member exceeds 500 m.
- **Vasiliki Conglomerate Member.** It consists of horizons and lenses of cohesive clast supported polymict conglomerates in alternations with sandstones and clay-marly material. The conglomerate horizons are up to 80 m thick, and die out gradually northwards, where their upper beds are gradually replaced by the Gavrolimni sandstone member. Clasts vary in size, are well rounded and the majority of them consist of pyritic and carbonate material of Pindos unit origin, having an average length of 3-4 cm and width of 2-3 cm. However, a few clasts with greater (L=20 cm, d=5 cm) or smaller dimensions (L=1 cm, d=0.5 cm) are also observed. The conglomerates outcrop mainly in four localities: i) southwest of Klokova, 20-100 m away from the Klokova limestones, having a thickness of 40 m, gradually thinning towards the north, (ii) north of Varasova and south of Evinos river, where the thickest horizons (up to 80 m) are observed, (iii) east of Varasova and west of the Kato Vasiliki village, and (iv) towards the Kokaliara high. This is the dominant member south of the Evinos river. North of the river it is heavily restricted and evolves to the Gavrolimni sandstone and the Potamoula shale members.

Kalavrouza Beds. It consists of 2-3 m thick whitish marls of Priabonian age (*Pellatispira madaraszi* HANTEN) (BIZON *et al*., 1963) that outcrops at the village of Kato Kalavrouza (Fig. 4a), on the western slopes of Klokova and are described as transitional beds between the carbonates and the flysch material (BIZON *et al*., 1963; FLEURY, 1980). However, based on our field observations, this member rests on a fault paleosurface that bounds the Klokova limestone (Fig. 4b). RICHTER *et al*. (1975) describe paleo-relief surfaces on the Eocene limestone (depressions filled with flysch material) suggesting that the emergence of the region is related to synsedimentary tectonism phenomena. We support that the existence of the fault surface, shown in Figure 4b, confirms RICHTER *et al*. (1975) interpretation. According to BIZON *et al*. (1963) these marls represent the transitional beds from the limestone to the flysch, indicating a normal transition from neritic carbonate to pelagic clastic sedimentation. However, their limited thickness (~2 m) and the fact that they are bounded by a N-S trending west dipping fault (Fig. 4b), suggests that the sedimentation

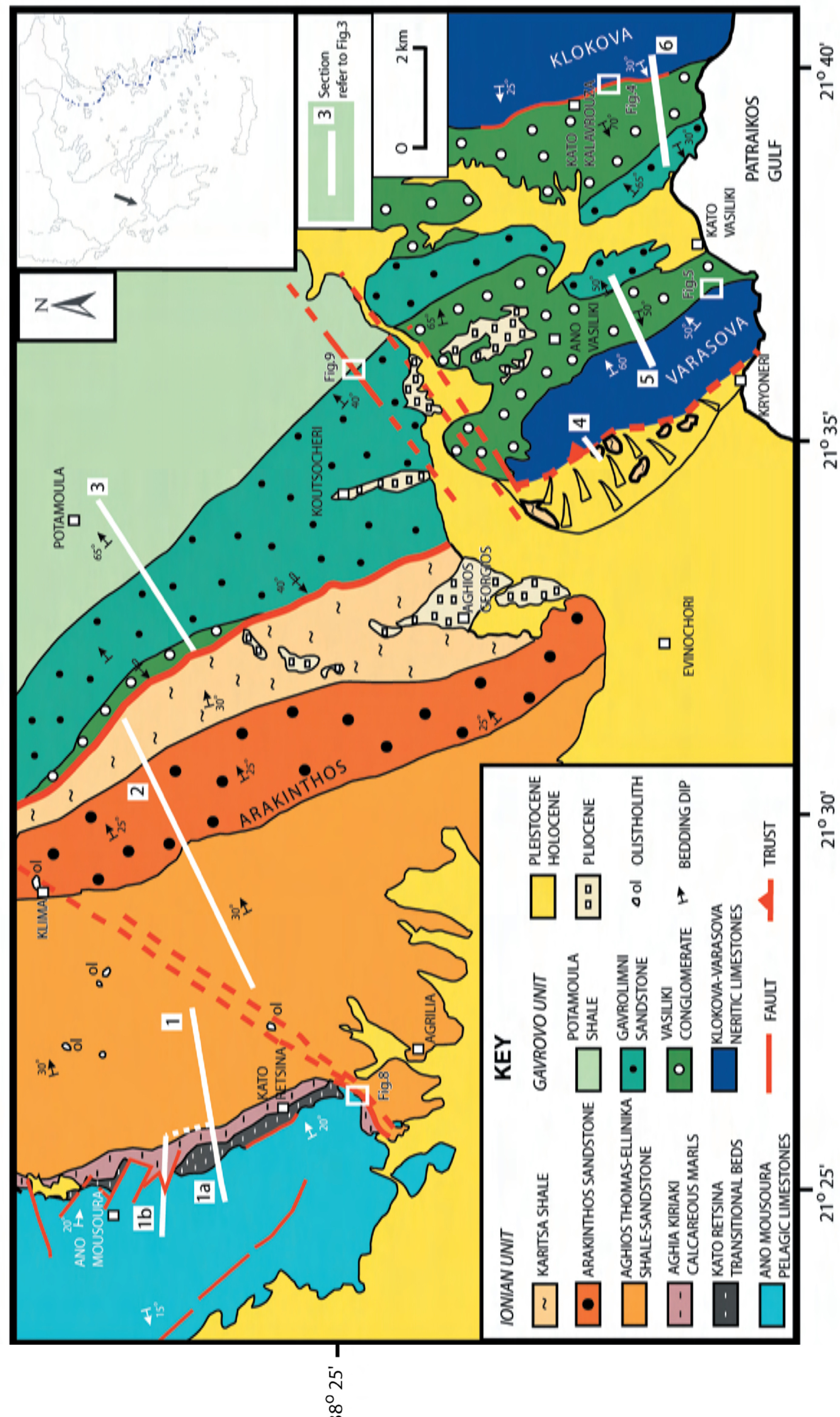


Fig. 2. Detailed geological map of the southern Aitoloakarnania. White bars represent the traces of the sections presented in Figure 3. Open boxes and figure numbers show the localities from where photos and figures are extracted and referred later in the paper.

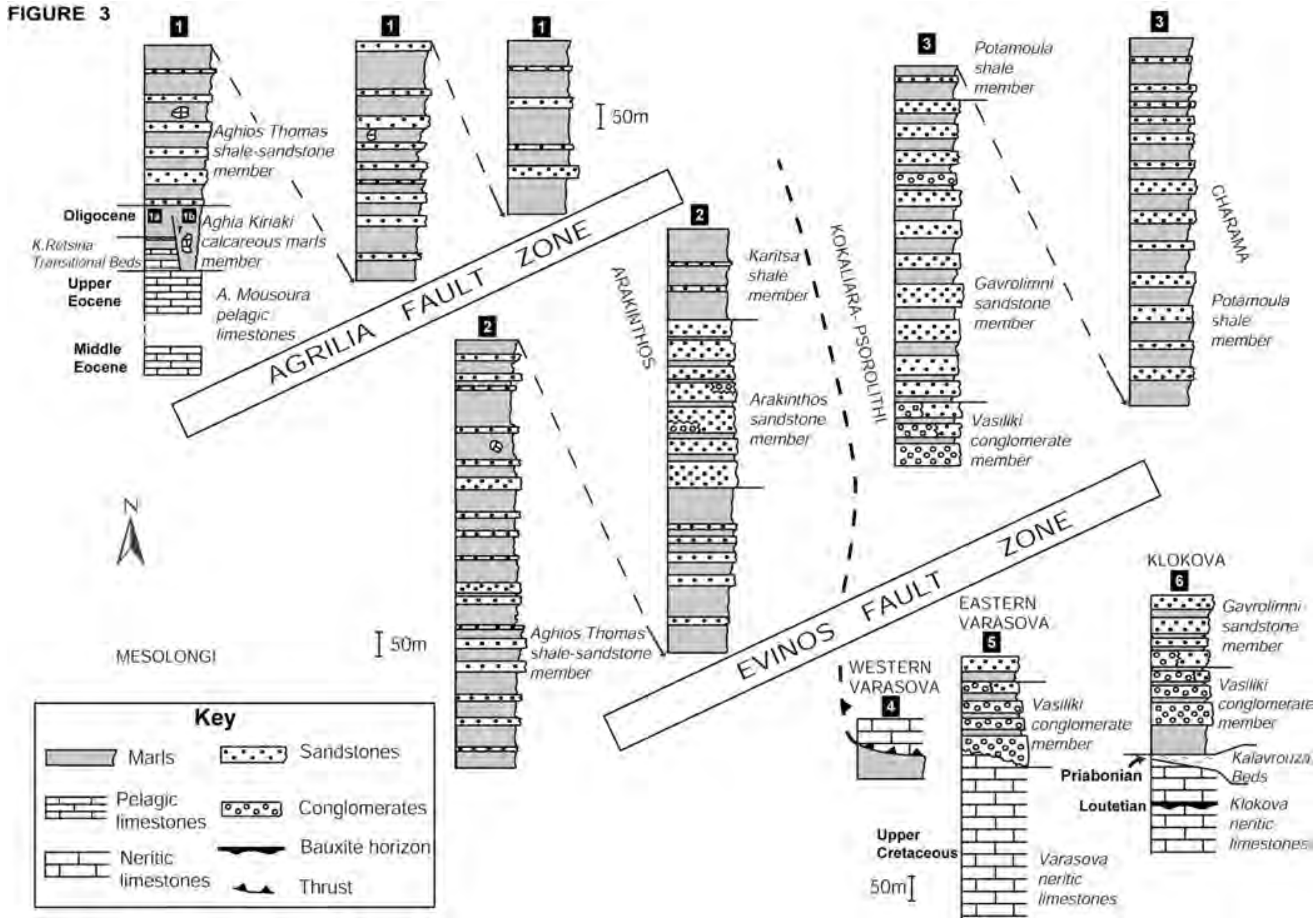


Fig. 3. Schematic section showing the lithostratigraphy of the area. Due to the complex and high spatial variability of the phases within the flysch succession, the lithostratigraphic structure cannot be presented through a single lithostratigraphic column for each unit. Instead a number of columns attached to different localities within the study area are presented. This interpretation provides us an overview that helps differentiating the Ionian from the Gavrovo flysch.

was disturbed by phenomena of synsedimentary tectonism as proposed by RICHTER *et al*. (1975). The latter has been widely demonstrated in several localities along the limestone/flysch boundary of the Gavrovo-Tripolis unit, particularly in the Peloponnesus (e.g. RICHTER & MARIOLAKOS, 1979 and references therein). Finally, it should be mentioned that the Kalavrouza member is not observed towards the Varasova high, due to the existing unconformity between the neritic limestone and the Vasiliki conglomerate member (Fig. 5).

Klokova Limestone. It consists of medium to thick-bedded neritic limestone of Paleocene-Eocene age (PHILIPPSON, 1890; AUBOUIN, 1959), brecciated at some locations, often bituminous, and outcrops at the western slopes of Mt. Klokova. It deposited in a shallow marine environment and has been disrupted by emergence as implied by the paleorelief formation and the deposition of the bauxite horizon during Lutetian times (LAPPARENT, 1934). The Klokova limestone was formed during Paleocene – Eocene times, represents the upward evolution of the Krioneri limestone and its thickness does not exceed 250 m (AUBOUIN *et al*., 1958; AUBOUIN, 1959; FLEURY, 1970; METTOS & KARFAKIS, 1991).

Krioneri Limestone. It consists of medium to thick-bedded limestone intensely karstified and locally dolomitized. In places, an unconformity is observed between the underlying limestone and the Vasiliki conglomerate member (Fig. 5). It contains rich algae fauna, foraminifera, gastropods and Lamellibranchiates of Upper Cretaceous (Cenomanian – Senonian) (FLEURY, 1970; 1980; METTOS & KARFAKIS, 1991). Strata dip 50°–60° towards the NE (Fig. 6). No dips towards the SW have been recorded, questioning all interpretations that describe the Varasova high as an anticline (B.P., 1971), SOTIROPOULOS *et al*., 2003). However, the bedding plane is not easily identified towards the north and western slopes of the mountain due to the extensive fracturing caused by several north and west dipping normal faults that have produced a tectonic cleavage, which provides a false impression of vertical bedding. This member is up to 600 m thick (B.P., 1971), and sedimentation occurred in a

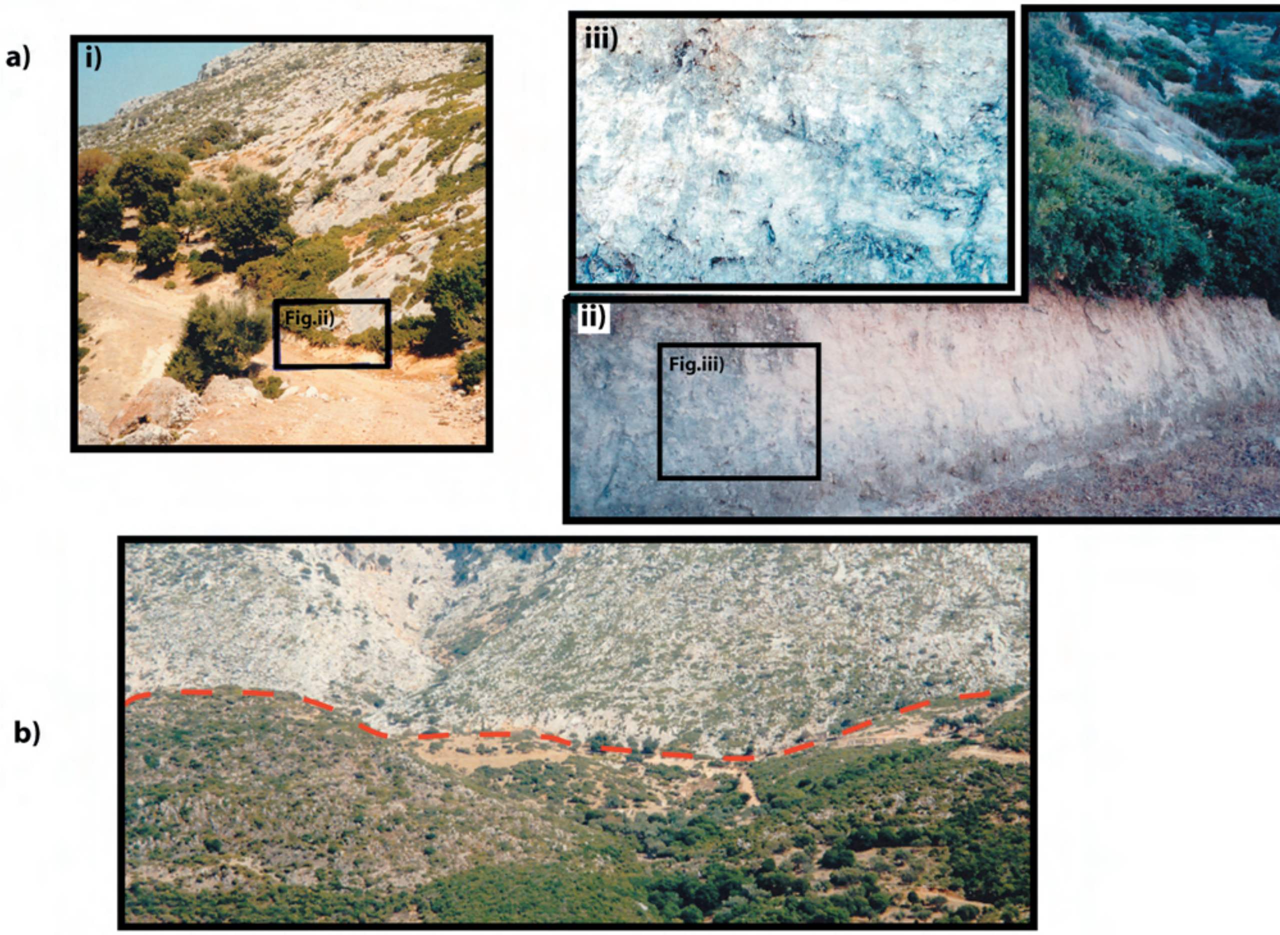


Fig. 4. a) View of the Kalavrouza beds. It comprises 2-3 m thick marls Priabonian in age (BIZON *et al*., 1963). According to BIZON *et al*. (1963) these marls represent the transitional beds from the limestones to the flysch, indicating a normal transition from neritic carbonate to pelagic clastic sedimentation. However, these beds are of limited thickness and are bounded by a N-S trending fault (Fig. 4b), implying that the sedimentation process was not normal, but disturbed by the fault activity. Moreover, RICHTER *et al*. (1975) describe nearby paleo-relief surfaces on the Eocene limestone, suggesting that the emergence of the region is related to synsedimentary tectonism phenomena. b) Distant view of the Kalavrouza N-S trending syn-sedimentary fault.

shallow marine environment and more specifically within the euphotic zone. This member outcrops only at Varasova. Northwards it is interrupted by the NE-SW trending Evinos fault zone.

Flysch beds generally dip 15º-40º towards the NE. However, in several localities strata dip 70º-80º and in particular north of the Evinos river and towards the Klokova limestone, strata even dip towards the SW. These variations are attributed either to sedimentation processes involving gravitional phenomena, such as submarine landslides (slumps), or to tectonism. For example, towards the Mt. Maurovouni, a succession of sandstone beds gives the impression of NW-SE trending isoclinic folds, but we believe that this pattern is due to gravitional phenomena that occurred during sedimentation. On the contrary, the conglomerate and sandstone beds observed east of the Mt. Varasova and north of the

Fig. 5. View of the unconformity between the neritic limestones and the conglomerate of the Vasiliki member towards the eastern flanks of Varasova. The conglomeratic horizons are folded and a NNW-SSE fold axis orientation is extracted.

Evinos river at the Kokaliara high respectively, are folded and a NNW-SSE fold axis orientation is extracted (Fig. 5). Finally, the area between the Klokova antikline and the Varasova high, is a well-known large scale NNE-SSW trending syncline.

The Ionian Unit

Ionian Flysch Formation. The Ionian flysch outcrops towards the western part of the study area and overlies the carbonate formations of the Ionian unit, having according to our calculations a total thickness of about 3 km. This value is almost double than the value reported on the published 1:50.000 geological map (KOURIS, 1996). The transition from carbonate to clastic sedimentation occurred during the Eocene-Oligocene boundary (FLEURY, 1980), leading to the formation of a few tens of meters thick transitional beds (Kato Retsina transitional beds, see below), even though phenomena of synsedimentary tectonism are also observed (PAPANIKOLAOU & LEKKAS, 2001). The flysch formation has been divided into the following four members:

- **Karitsa Shale Member.** It is the uppermost member, up to 150 m thick (PIPER *et al*., 1978), consisting mainly of shales partly with alternations of medium sized sandstone beds. Nanofossil dating has revealed an upper Oligocene age (NP24 and NP25, SOTIROPOULOS *et al*., 2003).
- **Arakinthos Sandstone Member**. It consists of medium to coarse-grained sandstone horizons up to 25 m thick, alternating with sandstone-pelite and pelite-sandstone beds of smaller thickness. Conglomerates are rare and of limited extent. This is the most characteristic member of the study area, outcrops at the top of the Arakinthos mountain range, forming an impressive steep relief towards the west (Fig. 7). On the contrary, eastwards, strata dip gently 25º – 35º towards the NE and the morphology is smoothed following the bedding dip. The Arakinthos member is interrupted and bounded by the Agrilia fault zone, near the village of Evinochori, towards the south and by the Evinos fault zone near the village of Klima northwards. The Arakinthos sandstone member is up to 350 m thick and its maximum thickness is observed a few kilometers south of the Klima village. In particular, a gradual decrease is observed both on the number and the thickness of the sandstone horizons towards the south, indicating a northern source of sediment supply.
- **Aghios Thomas Pelite-sandstone Member.** It consists of alternating pelites and sandstones and it is the dominant member of the Ionian flysch (KOURIS, 1996). Sandstone beds are generally thin, ranging from 5 to 60 cm, while shales and pelites are 5 – 25 cm thick. This member incorporates both large (size > 10.000 m^3) and small (in the order of few cubic meters) limestone olistholiths (Fig. 7). Its total thickness is estimated to 2200-2400 m approximately, almost a 1 km thicker than the thickness implied by the published geological map (KOURIS, 1996).
- **Aghia Kiriaki Calcareous Marl Member.** It represents the lower member of the Ionian flysch succession (KOURIS, 1996) and overlies either the transitional beds of Kato Retsina or the Ano Mousoura Eocene limestones. It consists of a few tens of meters thick calcareous marls that have been heavily disrupted by synsedimentary tectonism phenomena that occurred during the transition from carbonate to clastic sedimentation (PAPANIKOLAOU & LEKKAS, 2001).

Kato Retsina Transitional beds. It consists of transitional beds from the carbonate to clastic sedimentation. The transition occurs through alternations of limestone beds, marly limestones and pelites. During this grading up from the limestone to the flysch, carbonate sedimentation gradually dies out until clastic sedimentation dominates. According to FLEURY (1980), the transitional beds are of Priabonian age and more specifically, are dated close to the Eocene-Oligocene boundary. Due to phenomena of

Fig. 6. View of the Varasova high bounded northwards by the Evinos fault zone. Strata dip 50º–60º towards the NE. No dips towards the SW have been recorded, questioning all interpretations that describe the Varasova high as an anticline. Towards the north and western slopes of Varasova, the bedding plane is not easily traced due to extensive fracturing caused by several north and west dipping faults, providing a false impression of vertical bedding.

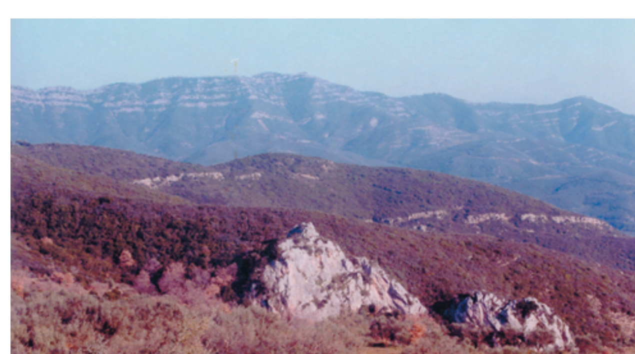


Fig. 7. View of the limestone olistoliths within the Ionian unit flysch (Shale-sandstone member of Aghios Thomas). Further to the east the massive sandstones horizons of the Arakinthos member are observed.

syn-sedimentary tectonism, the thickness of the Kato Retsina formation varies significantly. Moreover, in several locations transitional beds are missing and flysch rests directly on the limestone (PAPANIKOLAOU & LEKKAS, 2001). Overall, transitional beds are up to a few tens of meters thick and are observed in the area between Kato Retsina and Ano Mousoura villages (Fig. 2).

Ano Mousoura limestones: It consists of micritic, microbrecciated, thin-bedded to medium bedded limestones. Several fossils have been described in the literarture such as *Nummulites* spp., *Discocyclina* spp., Melobesiodeae, *Planorotalites compressa*, *Morozovella pseudobulloides*, *Fabiana cassis* etc, implying a Paleocene – Upper Eocene age (FLEURY, 1980; KOURIS, 1996). This member is 300-400 m thick and outcrops throughout the western section of the study area.

Overall, the flysch beds, throughout the Ionian unit flysch, dip gently 25º-35º towards the NE, forming a monotonous monocline, with the exception of the Aghia Kiriaki Calcareous Marl member that is partly disturbed by phenomena of synsedimentary tectonism. As a result, the sandstone horizons are generally undisturbed, implying that no significant normal faults, thrusts or folds exist, with the exception of the Agrilia and Evinos fault zones that bound the Arakinthos sandstone member northwards and southwards, respectively. This description is in disagreement with SOTIROPOULOS *et al*. (2003) interpretation who favor the presence of a major thrust close to the eastern boundary of the Arakinthos member.

Differentiating the Ionian from the Gavrovo flysch

Following the description of both geotectonic units above, several lithostratigraphic variations have been identified between the Ionian and the Gavrovo flysch. These are summarized below:

- Marls and pelites dominate in the Ionian unit flysch, whereas in the Gavrovo unit flysch their presence is limited.
- Conglomerates are the dominant lithology in the lower part of the Gavrovo flysch (Vasiliki Conglomerate member), but they are rare in the Ionian unit flysch.
- Despite the fact that transitional beds between the limestone and the flysch were deposited during the Priabonian in both units, significant variations are observed in their evolution. More specifically, in the Gavrovo unit the transition is abrupt and occurs either through a whitish 2-3 m thick marly material at Klokova, resting on a paleofault surface, or through an unconformity at Varasova. On the other hand, in the Ionian unit the sedimentation between the limestone and the flysch continued without interruption leading to the formation of relatively thick (up to a few tens of meters thick) transitional beds, even though at a few localities phenomena of synsedimentary tectonism are also reported.
- Several large and smaller olistholiths are observed within the Ionian flysch, in contrast to the Gavrovo unit flysch whose presence is rare.
- Each geotectonic unit is linked to a different source of sediment supply. According to our data on the distribution and thickness of coarse lithologies (e.g. Arakinthos sandstone member, Vasiliki Conglomerate member) two major sources of sediment supply can be traced. A northern source is indicated by the thinning of the massive sandstone member of Arakinthos towards the south, and a southern source involving also some eastward input, is indicated by the gradual thinning and disappearance of the Vasiliki conglomerate member, northwards of the Evinos fault zone.

Overall, paleocurrents within the Pindos foreland basin indicate longitudinal input from the north and lateral input from the east (GONZALEZ - BONORINO, 1996). Similar palaeocurrent flow trends, including a major N-S direction have been described within the Ionian (e.g. AVRAMIDIS & ZELILIDIS, 2001) and the Gavrovo unit (e.g. ALEXANDER *et al*., 1990) further North. B.P. (1971) supported that most of the paleocurrents in the study area were parallel to the axis of the trench, trending towards the north or the south, and in places they recognized also a significant transverse paleocurrent to the east. PIPER *et al*. (1977, 1978) identified two main sources of sediment supply in the region, involving two overlapping deep sea fans, a northern source near the eastern end of Trichonis lake which according to the authors, supplied the upper section of the flysch succession and a southern source along the gulf of Patras, which supplied the lower section of the flysch succession. The garnet rich heavy mineral associations of the Gavrovo flysch lying to the west of Klokova, fall on the trend of the overall heavy mineral composition of the Western Hellenic Flysch, suggesting to FAUPL *et al*. (1998) a supply from one of the internal major sources and not from a local one. In conclusion, following our data and the literature, we argue that each source relates to a different geotectonic unit. In particular, the northern source prevails on the western part of our study area and is linked to the Ionian unit flysch, whereas the southern source dominates the eastern part associated to the Gavrovo unit flysch deposits.

Thus, following all five points addressed above, we argue that there is no stratigraphic correlation between the eastern and western part, implying that the flysch is not continuous and common for both units, as it has been proposed by other workers in the past. Instead there is a boundary within the flysch succession (although weak in lithostratigraphic terms), separating the Ionian unit flysch from the Gavrovo flysch. This boundary correlates well with the tectonic boundaries observed in the area. In particular, southern from the Evinos fault zone, on the western flanks of Varasova, the boundary is localised forming a major thrust, which sets the rigid (stiff) Krioneri limestones of the Gavrovo unit on top of the Ionian flysch. Northern from the Evinos fault zone and east of the Aghios Georgios and the Karitsa villages, where limestones are absent, the boundary is more distributed and located along the fault system identified by PIPER *et al*. (1978). SOTIROPOULOS *et al*. (2003) based on seismic profiles and biostratigraphic analysis of nannofossils, identified the Gavrovo thrust on the same locality as the normal fault described by PIPER *et al*. (1978). Thus, the former thrust has probably been re-activated as a normal fault.

AGRILIA AND EVINOS FAULT ZONES AND THEIR IMPACT ON LITHOSTRATIGRAPHY

Two major transverse fault zones cross the study area; the Evinos zone at the eastern part and the Agrilia zone at the western part, which are characterized as strike slip faults (B.P., 1971; JENKINS, 1972; PIPER *et al*., 1978). In this Section, we investigate how these two major fault zones impact on the lithostratigraphy.

The Agrilia Fault Zone

The Agrilia fault zone is a NW-SE trending vertical structure that intersects and partly bounds the Ano Mousoura limestone and the lower members of the flysch succession (Fig. 8). It lies northwards of the Agrilia village and close to the settlements of Dafni and Klima, and its length exceeds 15 km (Fig. 3). The fault zone is well exposed in the Agrilia – Kato Retsina road section and bounds the limestone from the flysch deposits (PAPANIKOLAOU & LEKKAS, 2001). This zone is represented by: (i) a large fault on the limestone/flysch boundary, (ii) a smaller fault, within the limestone, about 150 m north of the limestone/flysch boundary and (iii) many minor faults trending parallel to the main structure. However, locating the fault trace within the flysch (further towards the NE) is a rather difficult task. For example, vegetation cover restricts the view. Additionally, the flysch is easily eroded and thus faulting is poorly preserved. In particular, the fault trace is poorly defined within the Aghios Thomas pelite sandstone member that lacks massive thick sandstone bodies, whose offset could easily reveal the fault trace. Nevertheless, further towards the NE at the Klima village the massive sandstone member of Arakinthos is heavily disturbed and inter-rupted, revealing the fault trace.

Striation data can be collected only at a single locality along strike the fault (e.g. along the Agrilia – Kato Retsina road section) and thus are inadequate to constrain the kinematics in a complete way, because fault slip directions may vary along strike the fault (e.g. ROBERTS, 1996). These striation data plunge 20º to 40º towards the 280º (see also VASSILAKIS, 1997), indicating an oblique right lateral fault.

The fault zone is exposed on the Agrilia-Kato Retsina road section and exhibits an approximately 15 m thick cataclastic zone. The material is intensely fractured and a progressive disappearance of limestone boulders is observed inside the fault gouge southwards from the limestone boundary (Fig. 8). In addition, several secondary fault planes exist due to branching of the main fault. Moreover, the bedding dip near the fault zone appears intensely disrupted and at places change dramatically. Overall, the Agrilia fault zone is an important tectonic structure not only due its significant length or the large thickness of its cataclastic zone, but mostly due to the important lithostratigraphic variations observed on either side of the fault zone. These variations include:

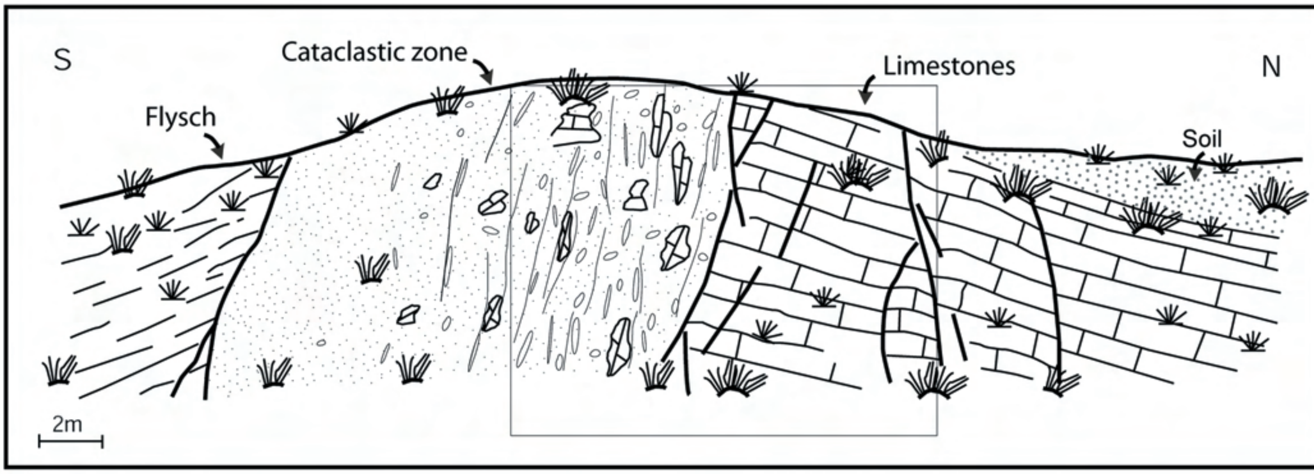
i. The abrupt interruption of the carbonate formations (Ano Mousoura limestones) and the transitional beds (Kato Retsina formation) of the Ionian unit towards the south.
ii. The abrupt interruption of the Arakinthos sandstone member towards the north.

Finally, the presence of large volume olistholiths (Fig. 7), within the flysch where the fault trace is inferred to be, indicates that this tectonic structure was also active during the flysch sedimentation (PAPANIKOLAOU & LEKKAS, 2001).

The Evinos Fault Zone

The Evinos fault zone is a NE-SW trending transverse structure, whose trace partly follows the present day Evinos river. We believe that the extensive deformation and fracturing caused by the fault activity, weakened the rock resistance of the flysch deposits to erosion in relation to neighboring less intensively deformed deposits. As a result, higher erosion rates along strike the fault trace, promoted the river path through the fault. We estimate that the fault length exceeds 20 km, but its southwestern end is buried below the Quaternary sediments and thus is not well constrained, so that it could even continue offshore. Similarly to the Agrilia fault zone several important lithostratigraphic variations are observed on either side of the fault zone. These variations involve:

i) The abrupt interruption of the Arakinthos sandstone member southwards towards the Evinochori village.
ii) The abrupt interruption of the Krioneri limestones south of the fault zone.



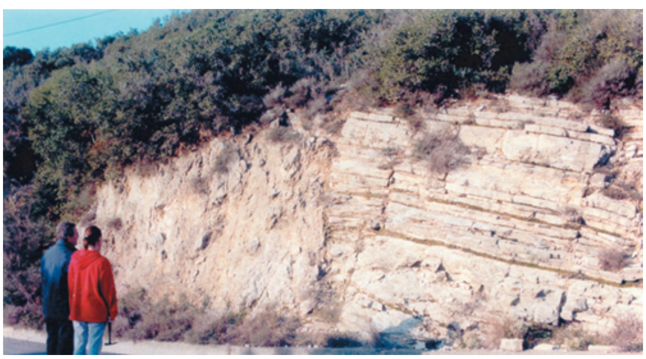


Fig. 8. Outcrop view of the Agrilia fault zone. A 15 m thick cataclastic zone and a progressive disappearance of limestone boulders towards the southern part of the fault gouge are observed.

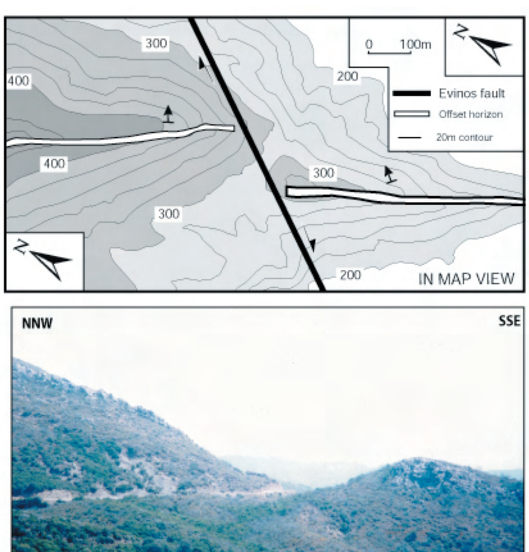


Fig. 9. a) Map view and b) Photo showing the horizontal offset of a characteristic horizon of the Gavrovo unit flysch, due to the Evinos fault zone activity. Horizontal displacement does not exceed 150 meters.

iii) The existence of large-scale morphological discontinuities towards the northern flanks of Varasova.

iv) Strata on either side of the fault zone have considerably different dips and dip directions.

v) The abrupt variations observed in both the thickness and phases of the Gavrovo flysch northwards and southwards the fault zone. In particular, coarse-grained lithologies (conglomerates and sandstones) dominate south of the zone, whereas fine-grained (shales and thinner sandstones) lithologies prevail north of the zone.

vi) The horizontal offset of the sandstone and conglomerate beds produced by the fault zone activity (Fig. 9).

The finite horizontal displacement at the locality of Figure 9, does not exceed 150 m. Considering that these displaced horizons belong to the lower-middle members of the flysch succession and are of Oligocene age, then the main phase of the Evinos fault zone activity, where most of the offset has occurred, predates the deposition of these horizons. It may also be that the Evinos fault zone activity fades out gradually and/or is terminated towards the upper members of the flysch succession where no offset has been revealed. For example, it is true that the Evinos fault zone does not offset the Pindos thrust (e.g. B.P., 1971; JENKINS, 1972; SOTIROPOULOS *et al*., 2003). At present day, the Evinos fault shows no sign of activity and overall can be characterized as a mainly syn-sedimentary structure.

According to the literature this zone is characterized as a pure strike slip structure. However, lithostratigraphy suggests that the main slip component is vertical and that the total throw of the fault zone exceeds 1 km, if the pre-orogenic formations are taken into account. Finally, considering that the Gavrovo thrust has not been horizontally offset by the Evinos fault, it is implied that either the Evinos fault zone activity pre-dates the thrust emplacement, therefore it is indeed syn-sedimentary and/or that it is a dip-slip normal fault.

DATA SYNTHESIS – DISCUSSION - CONCLUSIONS

In the following Section, we offer a short description of each geotectonic unit, summarize all the differences observed in the lithostratigraphy between the eastern and western part of the flysch and show how the lithostratigraphy is affected by the Evinos and the Agrilia fault zone activity.

The Gavrovo unit outcrops towards the eastern part of the study area and consists of pre-orogenic and syn-orogenic formations. More specifically it consists of neritic Cretaceous – Eocene carbonate formations that underlie flysch deposits. Clastic sedimentation began during the Upper Eocene, but the transition from the carbonate neritic sedimentation to the flysch was different in Klokova and Varasova highs. In Klokova, transition is abrupt through the deposition of 2-3 m thick marly material on a paleofault surface (Fig. 4b). In Varasova, there is an unconformity between the underlying neritic limestone and the Vasiliki conglomerate member (Fig. 5). The distinctive lithology of the Gavrovo unit flysch are the conglomerates (Vasiliki conglomeratic member) that are gradually graded up to sandstones beds, forming the Gavrolimni sandstone member. Coarse-grained material is of Pindos unit origin. Conglomerate and sandstone beds die out towards the NNW implying that the source of sediment supply had an opposite direction. Many horizons are abruptly interrupted or displaced across the Evinos fault zone. Flysch beds generally dip towards the NE. However, strata dip also towards the SW. This is attributed either to gravitational phenomena during sedimentation (west from Klokova limestone at Mt. Maurovouni) or due to folding (along strike the Psorolithi and Kokaliara highs or towards the eastern flanks of Varasova where conglomerates are deformed having a NNW-SSE trending fold axis (Fig. 5)). Indeed, both the slumps and the thick conglomeratic deposits observed towards the south-eastern part of the study area (between the village of Vasiliki and the Klokova high) indicate that the Gavrovo unit was the proximal part of the Pindos foreland basin.

The Ionian unit outcrops towards the western part of the study area and incorporates both pre-orogenic as well as syn-orogenic formations. Cretaceous – Priabonian limestones outcrop at the western part and grade up into the flysch through the presence of a few tens of meters thick transitional beds. However, in a few localities, transitional beds are missing and synsedimentary faulting is present. The lower member of the Ionian flysch consists of a few tens of meters thick calcareous marls that at several locations are disturbed by phenomena of syn-sedimentary tectonism. This member is followed by an irregular alternation of pelites, shales and sandstones beds of variable thickness, including also several limestone olistholiths. The upper sandstone Arakinthos member consists of massive medium to coarse-grained sandstones up to 350 m thick, which are overlaid by the Karitsa shale member. Conglomerate are rare and of limited extend and thickness. Strata dip gently towards the NE forming a monocline and no significant folding or faulting is observed. We found no structural or stratigraphical evidence for a major thrust appearing eastwards of the Arakinthos ridge as supported by SOTIROPOULOS *et al*. (2003). All strata form a clear monocline, which dips gently at 25°-35°. Additionally, on either side of the so-called Arakinthos thrust, no age gap on the flysch is observed, as it would be expected, since on either side of the thrust the flysch succession belongs to the same NP24 zone. Moreover, no repetition of beds is also observed, because the very distinctive massive member of Arakinthos observed in the immediate hanginwall, does not appear on the footwall. Finally, folds and some disturbance are evident only on the upper beds of the Karitsa member close to the Kokaliara high, where the morphology gets steeper. This is where the Gavrovo thrust is inferred to be and has also been confirmed by biostratigraphy (e.g. SOTIROPOULOS *et al*., 2003).

Following the above short description, we conclude that the western section of the flysch, incorporated within the Ionian unit, cannot be correlated to the eastern part, which is classified within the Gavrovo unit. Research groups in the past considered the flysch as one common succession resting between the Ionian and Gavrovo geotectonic units. Based on that viewpoint, they tried to correlate the eastern part of the flysch with the western part, but provided considerably different lithostratigraphic interpretations. However, we argue that there is no stratigraphic correlation between the eastern and western part, implying that the flysch is not continuous and common for both units. Some significant variations have been revealed in the lithostratigraphic structure of both units.

These variations involve:

- The transition processes from carbonate to clastic sedimentation. Although this transition occurred during the Priabonian (close to the Eocene-Oligocene boundary) in both units, their evolution was different. More specifically, in the Gavrovo unit the transition is abrupt and occurs either through a whitish 2-3 m thick marly material resting on a paleofault surface at Klokova (Fig. 4), or through an unconformity at Varasova (Fig. 5). On the contrary, in the Ionian unit the sedimentation between the limestone and the flysch continued without interruption leading to the formation of relatively thick (up to a few tens of meters thick) transitional beds, even though at a few localities phenomena of synsedimentary tectonism are also reported. These phenomena are possibly related to the presence of large olistholiths at the lower members of the Ionian flysch (Fig. 7).
- The different lithologies of the Ionian and Gavrovo flysch formations. The Gavrovo unit flysch mainly

consists of coarse lithologies, such as conglomerates in the lower members and sandstones in the medium members. On the other hand, shale is the dominant lithology of the Ionian unit flysch, whereas conglomerates are extremely rare and sandstones prevail only on the upper massive sandstone member of Arakinthos. Several large and smaller olistholiths are observed within the Ionian flysch, in contrast to the Gavrovo flysch whose presence is rare.

- The different sediment supply source for each unit. Each geotectonic unit is linked to a different source of sediment supply. According to the distribution and thickness of coarse lithologies (e.g. Arakinthos sandstone member, Vasiliki Conglomerate member) there are two main sources of sediment supply. A northern source is indicated by the thinning of the massive sandstone member of Arakinthos towards the south, and a southern source with some eastward input is indicated by the gradual thinning and disappearance of the Vasiliki conglomerates member, northwards of the Evinos fault zone. In conclusion, the northern source prevails on the western part of our study area and it is linked to the Ionian unit flysch, whereas the southern source dominates the eastern part associated to the Gavrovo unit flysch deposits. This is in agreement with the major published paleocurrent measurements reported for the area.

The idea of separating the Ionian and the Gavrovo flysch is in agreement with the heavy mineral compositions observed. For example, in the NW Peloponnesus the differentiation of the Ionian and the Gavrovo flysch has been possible on the basis of elevated chrome spinel content (FAUPL *et al*., 2002). A future detailed study on the heavy mineral composition of the area could provide more evidence on the division of the flysch as well as the paleocurrent directions.

Biostratigraphic analysis and nanofossils dating clearly show that both the Ionian and the Gavrovo flysch are of Oligocene age (SOTIROPOULOS *et al*., 2003) with a similar initiation age (AUBOUIN, 1959; BIZON *et al*., 1963; FLEURY, 1980; SOTIROPOULOS *et al*., 2003). The latter implies that these two flysch sequences were deposited synchronously, in two separate basins, which were divided by the thrust/tectonic boundary. This boundary probably produced a positive topographic relief within the sea floor, which acted as a barrier, preventing and/or restricting the expansion of conglomerates towards the west or even the expansion of the Arakinthos sandstones to the east. The latter shows that the eastern (Gavrovo) basin (proximal part) was not filled and it is indeed an example of underfilled conditions. More evidence which agree with this scenario of thrust movement uplifting the topography comes from the conglomerate stratigraphy. In particular, ALEXANDER *et al*. (1990) based on the presence of clast supported breccio-conglomerates and gravity flows sourced from gravity highs within the basin, supported that thrust culminations created a basin floor topography, which controlled and deflected the turbidity current pathways. Even though the authors have not distinguished between different geotectonic units and basins, we believe that these data add more confidence to our interpretation.

Sedimentary facies and paleocurrent patterns in the Pindos foreland basin indicate synsedimentary tectonic activity and this has been related to the advance of the thrust front through the basin (e.g. CLEWS *et al*., 1989; ALEXANDER *et al*., 1990). In Figures 2 and 3, it has been demonstrated that the NE-SW trending transverse fault zones of Evinos and Agrilia were indeed active during sedimentation, having a pronounce effect on the lithostratigraphy. More specifically, the Evinos fault zone bounds: i) the Varasova and the Klokova limestones towards the north, and ii) the Arakinthos massive sandstone member towards the south. On the other hand, the Agrilia fault zone bounds: i) the Eocene pelagic limestones of Ano Mousoura as well as the transitional beds of Kato Retsina formation towards the south, and ii) the massive sandstone member of Arakinthos towards the north. No sign of recent activity has been traced and field data indicate that both zones mainly acted as syndepositional structures. Based on the lithostratigraphy, a significant vertical offset is evident for both units, questioning the available published data that consider them as pure strike slip structures. In particular, a significant vertical offset (that exceeds 1 km, taking into account the pre-orogenic formations) is calculated for the Evinos fault zone, whereas its horizontal offset is limited (does not exceed 150 m based on the displacement of the lower to middle members of the Gavrovo flysch). Finally, whether these zones are partly inherited structures from the pre-orogenic phase, is still an open question.

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